HOUSE OF COMMONS

Environmental Audit Committee

Oral evidence: Net zero aviation and shipping, HC 520

Wednesday 1 December 2021

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Watch the meeting

Members present: Barry Gardiner (in the Chair); Mr Robert Goodwill; Helen Hayes; Ian Levy; Caroline Lucas; Jerome Mayhew; John McNally.

Questions 81 - 169

Witnesses

I: Matt Gorman, Director of Carbon Strategy, Heathrow Airport; Glenn Llewellyn, Vice-President, Zero Emission Aircraft, Airbus; Val Miftakhov, Founder and CEO, ZeroAvia; and Hannah Tew, Director of Air Mobility, Connected Places Catapult.

II: Tim Johnson, Director, Aviation Environment Federation; and Leo Murray, Director of Innovation, Possible.

Written evidence from witnesses:

- Heathrow Airport
- Airbus
- ZeroAvia
- Aviation Environment Federation
- Possible

Examination of witnesses

Witnesses: Matt Gorman, Glenn Llewellyn, Val Miftakhov and Hannah Tew.

Q81 **Barry Gardiner:** Welcome to the second session on net zero aviation and shipping and the oral evidence that we are taking today from our witnesses at the Environmental Audit Select Committee. Could our witnesses introduce themselves?

Val Miftakhov: Val Miftakhov, CEO and founder of ZeroAvia. ZeroAvia is working on the zero-emission power plants for commercial aviation. We are based in Cotswold Airport here in the UK.

Hannah Tew: Good afternoon. My name is Hannah Tew. I am Director of Air Mobility at Connected Places Catapult. Connected Places Catapult is the UK's innovation accelerator for cities, transport and place leadership, backed by the UK Government through Innovate UK funding and leading on key decarbonisation with the Department for Transport in maritime, logistics and flight.

Barry Gardiner: That is quite a mouthful.

Matt Gorman: Matt Gorman. I am carbon strategy director for Heathrow Airport, the UK's hub and largest port by value. I am delighted to be here to give evidence on how we can take the carbon out of flying. We are at the beginning of what I think is a very exciting transition.

Glenn Llewellyn: Glenn Llewellyn. I am vice-president for the zero-emission aircraft project at Airbus. At Airbus, we have an "and, and, and" strategy to decarbonisation, supporting multiple pathways, including sustainable aviation fuel and hydrogen in its raw form, where we have the ambition to bring the first zero-emission large commercial aircraft to service by 2035, powered by hydrogen.

Q82 **Barry Gardiner:** Thank you very much. Val, ZeroAvia has achieved the world's first hydrogen-powered flight. Can you tell us about that and the future ambitions of ZeroAvia?

Val Miftakhov: We have achieved the most out of all the entities in demonstrating the technology, the hydrogen electric technology. We have flown out of our Cranfield Airport base in 2020 the world's first certificated aircraft, powered through hydrogen, a hydrogen electric engine. It was a six-seat vehicle. This was our second prototype and that was supported by the UK Government, the ATI and BEIS funding.

From that, we started working on the larger vehicle that we have based in our Cotswold Airport location in Kemble. That is a 20-seat aircraft, a twin Dornier 228 airframe that is used in commercial settings quite a bit. This aircraft is getting ready for its first flights right now. We are already starting ground tests of the fully integrated system in December, this month, and hopefully will have our first flight of that large vehicle in the next few weeks.

Q83 **Barry Gardiner:** Thank you very much. Glenn, can I turn to you about Airbus's ambitions for developing commercial zero-emissions flights?

Glenn Llewellyn: We announced to the public in September last year the ambition to bring to commercial service a large commercial zero-emission aircraft by 2035. Our focus is 100-seat aircraft, 1,000 nautical miles and upwards. That is the market that Airbus primarily focuses on.

We have a number of activities under way: a flight-test demonstration plan as well as configuration-selection activities ongoing. It is going to be important that we flight-test significantly in the megawatt-range propulsion systems before we launch a programme. When we launch a programme, we are talking about pressing the button on a €10 billion investment, so it is really important that we have done the necessary due diligence up to the point that we make that pretty big decision.

We made the announcement in September last year, recognising that this is an activity—an ambition—that is only going to be achieved with the engagement of a broad ecosystem, whether we are talking about a technology ecosystem or a regulatory ecosystem or even a hydrogen ecosystem. Many of you will be aware that hydrogen does not exist at airports today, so our communication last year was to start to engage the energy sector, and airports in particular, to start ramping up plans to get low-cost green hydrogen available at airports. Without the energy available, there is no point having a zero-emission aircraft. The two need to be developed together.

Q84 **Barry Gardiner:** Matt, in your written evidence, you at Heathrow told us that net zero aviation would make it possible to fly "guilt free". Can you explain what role airports will have in meeting the net zero target for aviation?

Matt Gorman: Yes, and I will focus my comments on taking the carbon out of flying—in the air. We are doing a lot of the ground as well, which I am happy to explore, but it is less the focus of this inquiry, I think.

There are three big steps that we think will help us take the carbon out of flying. The "guilt free" was a reference to how can we protect the benefits that we know aviation brings, but do that in a world without carbon. Three big steps: more efficient aircraft and operations, sustainable aviation fuels and zero-emission flights. I will give you a quick sense of our role in each of those.

More efficient aircraft is primarily a role for airlines to invest in new aircraft. Heathrow has a role in more efficient operations in investing, particularly in modernising airspace. We are planning to invest around £70 million over the next decade in modernising the roads in the sky around Heathrow, if you think of it that way. That global change programme to modernise airspace—

Q85 **Barry Gardiner:** Does that mean you will stop flying over Kew Gardens?

Matt Gorman: I do not think it will make changes to the landing routes probably that close to the airport.

Barry Gardiner: What a shame. One of the great things that destroys the peace of those beautiful gardens.

Matt Gorman: What I would say very quickly on that is that individual aircraft are getting quieter, and we may be able to bring them in a bit more steeply to land, which would make them a bit higher at least. That combination could offer benefits. We are investing in that. There is also a programme of around £80 million over the next five or so years just in improvements on the round-plug-in air conditioning, electric air conditioning for aircraft, to give one example.

We see that efficiency measures will take us so far, but to get towards net zero we need to do two big things: change the fuel to sustainable aviation fuels, and change the plane through the kind of technologies that Val and Glenn have talked about.

We see SAF as a key solution, particularly for an airport like Heathrow, which is where emissions from mid- and long-haul flying are very significant—probably 70% to 80% of the total carbon footprint of Heathrow. We see sustainable aviation fuel as the main solution even by 2050. Our main role there is advocating Government policies to make it economic. It is a proven solution, but it costs more than kerosene, so we need a combination of a mandate, price-support mechanisms and capital support from Government to get it going. I am happy to explore those policies further. We are also introducing a landing-charge incentive for SAF from next year to help close the price gap, which could be up to £100 million by 2024, so a good financial incentive.

For zero-emission flights—by that I am referring to new, particularly for Heathrow, hydrogen aircraft as have been described—our main role there is research to understand the infrastructure implications and, at a later stage, either investing or at least supporting others to invest in distribution of hydrogen, storage of hydrogen and moving it around the airport. I am happy to expand on those, but that is the brief view.

Q86 **Barry Gardiner:** You have put quite a focus there on sustainable aviation fuel. Under the Government's Jet Zero consultation, I am sure you are aware of the different pathways that they have outlined of do nothing and the different scenarios. Even with sustainable aviation fuel, high ambition and a breakthrough on zero-emissions aircraft, it does not get us to net zero, does it?

Matt Gorman: The Government's projections do not. Our own ones are a bit more optimistic on the potential for sustainable aviation fuel, particularly as we shift to synthetic fuel—combining renewable hydrogen and carbon captured from the air—but even in our projections we still have some residual emissions in 2050 that will need to be removed by engineered removals.

Q87 **Barry Gardiner:** It is not quite guilt free, then. Less guilt is what you are talking about.

Matt Gorman: The goal is net zero. That does not mean that every single sector is at absolute zero. In the UK, aviation is one, I think the Committee on Climate Change would say, along with agriculture, of the two main sectors where there are still some emissions that need to be removed. Our view would be that if you have robust, engineered removals, which are under development now and need to scale up, if there are some small—and we think they will be small—residual emissions from aviation by 2050, for every tonne we emit you can take it out again, so you are at net zero.

By the way, beyond 2050, through both sustainable fuels—Glenn and Val will be more qualified to comment on hydrogen aircraft—we think absolute zero is a possibility for aviation.

Q88 **Barry Gardiner:** Hannah, can I turn to you finally and ask, what are the benefits to communities from getting to zero-emissions flight?

Hannah Tew: We are on the cusp of the third revolution of aviation; the first was the Wright brothers, the second was the jet engine and the third is flexible aviation—new classes of air vehicle that will bring our communities together at a sub-regional level and connect us like never before. For these new classes of vehicles, some can fly in our current regulatory framework and some of the technology has already been demonstrated in 2021. Some of these vehicles need no pilot on board, so we do need some regulatory reform to enable the opportunities there to be maximised.

Through the Future Flight Challenge, Project SATE, the Highlands and Islands Kirkwall Airport saw the first electric aviation flight earlier this year, in August. Later in the same month, the To Zero Project flew in Cornwall. These are retrofitted vehicles with Ampair, SME, working with Rolls-Royce to make those vehicles. This revolution can unleash a massive economic potential, bringing together communities that are looking at levelling up in the coming decade and beyond.

Q89 **Barry Gardiner:** You mentioned regulatory reform that is required there. Could you expand on that?

Hannah Tew: Certainly. At the moment, in our standard regulatory framework, the pilot of a vehicle needs to be in visual line of sight, VLOS. In order to maximise the potential from new classes of vehicle, such as drones that are un-crewed aerial vehicles, or urban air mobility, advanced air mobility—think electric flying taxis—they will be pilot free, un-crewed. That means you need to fly beyond visual line of sight. Currently, our regulatory framework does not allow for this. Therefore, we need innovation within our digitalisation within our traffic management systems and support from the regulator in order to enable these classes of vehicle to fly safely in our airspace.

Q90 **Barry Gardiner:** So that it is absolutely clear, are we talking here about

the transportation and communication of goods or are we talking about the transportation of people?

Hannah Tew: We are indeed talking about both—the transportation of goods port to port. We are aware of projects looking at half a tonne payload moving goods, but also the transportation of people using helicopter-size vehicles that are electrically powered, born green.

Q91 **Barry Gardiner:** And where there would be no pilot?

Hannah Tew: Initially, we will have piloted vehicles in our current regulatory framework in order to commercialise. However, the vision out to 2050 is that the beyond visual line of sight regulations will unlock, and we will be able to fly autonomous and automated flights.

Barry Gardiner: Thank you. I will pass over to my colleague Jerome Mayhew.

Q92 **Jerome Mayhew:** Thank you very much, Chair. Picking up on that last point, no doubt when Barry was a boy, going back to the 1940s and 1950s, and when I was a boy in the 1970s, I used to watch TV programmes that would say that personal flight, personalised flight, flying taxis were always going to be in 20 years' time, that is the future. It has always been something in the next generation that will happen, but it never does happen. Do you think it really will happen this time?

Hannah Tew: Through the UKRI's Future Flight Challenge, we are looking at live demonstrations of these vehicles flying in 2024 in realistic airspace scenarios. We have seen that our colleagues with me on the panel are flying their classes of vehicle already. The "Skies Without Limits" paper predicts that by 2030 there will be 76,000 drones flying in our skies with a net benefit to the economy of £42 billion. The Future Flight Challenge strongly suggests that poorly connected regions could benefit from a cost reduction of 47% cost over train travel.

We have organisations in the UK such as Vertical Aerospace, based in Bristol. It is partnering with the Paris Olympics and is working with a number of other investors. It is looking to demonstrate in 2024 and fly commercial flights in 2025. These will be piloted because our current regulatory framework does not allow for the autonomous flight, but there is a view that we will go through a number of stages to get there.

Q93 **Jerome Mayhew:** Cutting you short there, whereas as the environmental lobby has often seen the approach to net zero as a removal away from flying, you are anticipating a proliferation of flying as we develop battery technology. Is that how you see the future?

Hannah Tew: I see the proliferation of a different use of a new transport mode, flexible aviation.

Q94 **Jerome Mayhew:** Thank you, that is interesting. Glenn and Val, I am going to focus my next question on you. Glenn, could you start and then, Val, take it on from a smaller aviation perspective and Glenn from a very large scale? Can you explain the differences in the technology that we are

currently exploring—that is hydrogen fuel cells, hydrogen burn and e-fuels—and can you give an assessment of how developed each of these technologies currently is?

Glenn Llewellyn: Let's start with e-fuels. E-fuels are essentially a synthetic hydrocarbon. It is a human-made kerosene and hydrocarbon because you can take hydrogen from a renewable energy source, plus you capture CO_2 from the air, and you combine the two in what is called a Fischer–Tropsch process in order to create this e-fuel or power-to-liquid synthetic fuel.

Our aircraft are already compatible with that fuel type, up to the 50% blend mixed with jet A1, so it is a technology that can be implemented already today on existing aircraft, similar to the biomass-based fuels, part of the sustainable aviation fuel family. The big difference between biomass based and e-fuel or power-to-liquid synthetic fuel is the scalability. Biomass has a limited feedstock whereas the synthetic pathway is much more scalable.

Q95 **Jerome Mayhew:** Presumably that process is pretty energy intensive in its own right, is it?

Glenn Llewellyn: It is more energy intensive than digging kerosene out of the ground. That is pretty much the case for all synthetic fuel products that we might be interested in for the transition to net zero, absolute zero or any of the targets that we are setting ourselves. Digging oil out of the ground, in terms of primary energy, is very low energy intensity. That is why it has been such an interesting fuel type for us over the last few hundred years.

Q96 **Jerome Mayhew:** And hydrogen burn and hydrogen fuel cells?

Glenn Llewellyn: Yes, hydrogen burn—we tend to call it hydrogen combustion—and hydrogen fuel cells are essentially where you use hydrogen in its raw form on the aircraft. That means that you store the hydrogen in its liquid state. That is our primary target because that is when you have an interesting volume and mass on board the aircraft. Then you consume it in fuel cells or in gas turbines. The gas turbines essentially would look identical to gas turbines that we have today except that you have different injectors and combustion chamber. Then you have a hydrogen fuel system to make the link between the hydrogen storage and where you consume the hydrogen.

You can have a combination of fuel cells and hydrogen combustion on your aircraft in a hybrid configuration. You have probably heard about hybrid electric cars, and hybrid electric aircraft even, in the past. As soon as you go to hydrogen you start to have a lot more energy per kilogram—that is an important parameter for aviation—using fuel cells compared to using batteries. Fuel cells are very efficient in certain phases of flight, a lot more efficient than a gas turbine, so that combination can optimise the energy usage on board the aircraft.

Q97 Jerome Mayhew: Thank you. Val, do you have anything to add to that,

particularly in reference to hydrogen fuel cells and how that works?

Val Miftakhov: To add to what Glenn said, all these sources that you mentioned start from hydrogen, hopefully green hydrogen produced in the zero-emission way from renewable energy, ideally through electrolysis. That allows us to decarbonise the whole thing. Green hydrogen is very important for synthetic fuels, for hydrogen combustion and for hydrogen fuel cells.

On synthetic fuels, in addition to that being a relatively less efficient fuel-production approach, it is less efficient on the utilisation side because the turbine engines are generally—Glenn mentioned it a little bit—less efficient than the fuel cells can be. That is where we see a hierarchy among these fuels.

Synthetic aviation fuels can be available today; the technology exists. You can make them, you can procure them, you can blend them to use in the aircraft, but they are fundamentally more expensive and more complex to create than hydrogen because you start with hydrogen and then you need to add all the chemical process and the infrastructure to build them. With hydrogen technologies—hydrogen combustion or fuel cells—you can use that hydrogen directly in the aircraft, which is a simpler process from the fuel-creation standpoint and utilisation, so it is cheaper that way.

Out of those two technologies—hydrogen combustion and hydrogen fuel cells—fuel cells are the most efficient. For relatively small aircraft, we are focusing now on the 20-seat, but have already started working on a 70- to 90-seat aircraft, and eventually ZeroAvia is planning to cover all sizes of aircraft with our technology, but we already working on up to 90 seats. We have announced some partnerships with airlines that are looking to fly our aircraft.

For that size aircraft, fuel cells are 50% more efficient than a similarly sized turbine engine. What that means is that you will utilise less fuel to make the same amount of propulsion or the same amount of travel, which means that the costs go down quite a bit and you need less fuel on board the aircraft. For hydrogen one of the biggest problems to bring that fuel to aviation is that it is much better on weight, but it is challenging on volume, so you do need to reduce the amount of fuel that you use. With fuel cells you can do it.

How do fuel cells work? It is an electric chemical, a catalytic device, that takes hydrogen from the tanks on board the aircraft, oxygen from the air and combines them catalytically in the fuel cell to produce electricity. The downstream of that is electric motors rotating the propulsors. That is a fundamentally more efficient approach and a low-temperature, low-pressure approach relative to combustion, which means that maintenance costs are also going to be lower.

Q98 Jerome Mayhew: If I can précis that, your view is that a fuel-cell approach gives you further kilometres of travel per kilogram of fuel

carried?

Val Miftakhov: That is right.

Q99 **Jerome Mayhew:** Hannah, that brings me neatly to you. There has been a lot of debate and scepticism, I think it is fair to say, about the distance that these novel technologies are going to be able to transport at a commercial level. What are your views on how far a hydrogen or electrically powered flight might be able to travel? Are we looking at zero-emission flights being reserved only for the domestic and short-haul sector or can you see it going for the long-haul sector as well?

Hannah Tew: Certainly in the short term, I think there is impact to be had in this decade with electric and hydrogen vehicles. We can see that Hyundai, which is investing £1.25 billion in the UK in urban air mobility, is looking to commercialise in 2028. Yes, these will be domestic, they will be sub-regional and they will be regional.

Q100 Jerome Mayhew: Your definition of sub-regional and regional?

Hannah Tew: Inter-city. There is a paper that was published this year called "Distributed Aviation". This is a different model for the way that we conduct internal UK flights using not only our network of airports, but the general aviation airfields that are available to us and the integration of new classes of aerodrome called vertiports to enable these new classes of vehicle to operate.

I need to look to my colleagues with regard to the longer-haul flights and the opportunities for those. Definitely everything that is being talked about in the industry at the moment, we are looking at the middle of the next decade before those longer journeys are viable.

Q101 **Jerome Mayhew:** That is interesting. Glenn, do you have any views from the perspective of Airbus? I see you have identified three different types of potential passenger vehicle for the next 20 or 30 years. What is your degree of confidence in the progress of those?

Glenn Llewellyn: The three types that we revealed last year, one of them is a turboprop aircraft, which is approximately 100 seat, 1,000 nautical mile range. The other is a single-aisle type aircraft with about 200 seats and 2,000 nautical mile range. Then there is a blended-wing body, a flying-wing concept, that we also revealed. I would highlight that the blended-wing body is an interesting concept. You will probably be aware that hydrogen requires more volume than kerosene to store it. Naturally, inside a blended-wing body configuration you have more volume.

None the less, that configuration is not likely to be the first zero-emission aircraft that we bring to the service. It is much more likely that we will go for a more classical, what we call tube-and-wing, configuration. In terms of potential, we see pretty huge potential, all the way from what Val was talking about and ZeroAvia is doing in the general aviation space and

upwards through 100 seat, 200 seat, 1,000 nautical miles, 2,000 nautical miles.

We have work to do on the technology side of things and we for sure have things to happen on the ecosystem side, but what we are seeing is more and more sectors pushing for hydrogen. It is going to increase hydrogen availability across our countries, across our regions, and it is going to bring the cost down, which we believe will make hydrogen flying cost competitive. If we consider one of the key metrics that we measure ourselves against—cost per tonne of CO_2 avoided—we see hydrogen being pretty competitive in terms of cost per tonne of CO_2 avoided. That will encourage a larger and larger market for those vehicles.

One last point that did not come out when we were comparing the different options earlier: hydrogen also has potential to deal with local emissions like NOx and particulate matter and contrails. When we look at the complete climate impact of aviation, we see potential in hydrogen that we do not necessarily see in some of the other options. That is a further reason we think hydrogen is of interest.

Q102 **Jerome Mayhew:** We have heard in the evidence so far from all the panellists quite positive and optimistic assessments of the future of aviation travel in a net zero carbon environment, yet the Government's most positive modelling up to 2050 suggests that there is only going to be a 12.5% abatement coming from zero-emission flights. That is about 7 megatonnes of CO_2 per year. Is this a fair assessment or do you think the Government are being unduly pessimistic?

Glenn Llewellyn: A lot of the technology is available. We spoke about power-to-liquid synthetic fuel earlier and biomass-based fuels. Those fuel types do not require any invention. Those fuel types exist, the processes are known, and they can be deployed. The aircraft that we are already delivering allow us to use those fuel types, so there is no limitation in terms of technology to be bringing down dramatically the CO_2 emissions from aviation.

We need the policy instruments in place and the incentives in place to make sure that those pathways are scaled up significantly. We need to support the airlines in the transition, like we have been seeing support for the energy sector in its transition. If we put the right policy instruments in place, we can certainly achieve the ambitious targets that we need to in order to achieve the 1.5-degree scenario in the Paris Agreement.

Val Miftakhov: That number might be referring to zero-emission at the aircraft level. Zero-emission technology is novel propulsion technologies by 2050. In that case, we believe that it is conservative. Not just us, but we have recently seen the reports, for example, from world economic forums supported by McKinsey & Company that put, I believe, hydrogen specifically, just hydrogen, at about 25% off the flight by 2050. That includes hydrogen combustion and hydrogen fuel cells. Therefore, we definitely think that more aggressive than 12.5% can be possible.

Q103 **Jerome Mayhew:** Finally, we have heard how digging kerosene out of the ground is a cheap way of finding your fuel source, which suggests that the fuel of the future is going to be more expensive. Val, in the evidence that I have read, you seem to be challenging the assumption that it is going to be more expensive to fly in the future, the literal input costs into the aircraft are going to be more expensive. When commercially available, how much more will zero-emission flights cost than those powered by kerosene or do you challenge that assertion?

Val Miftakhov: Yes, we challenge that assumption. There is a little bit of a question mark on what timeframe exactly the crossover happens. We think that small aircraft—for sub-regional aircraft, like a 20-seat aircraft, which we are looking to launch in about three years—at that time will be cost competitive because small aircraft engines are typically the least efficient and the cost of fuel for those operators is the highest because of the low volumes. We will be able to provide the break-even with jet fuel at around $5 or $6 a kilo per cost of hydrogen. We already see that kind of cost in renewably powered projects throughout the world on hydrogen. When we have the larger aircraft—60, 70 and 80-seat aircraft, maybe five or six years out—we could also see the break-even relatively quickly after that.

The macro point there is that with renewably produced hydrogen you almost have zero marginal cost of fuel because your renewable production, whether it is wind, hydro or solar, is effectively zero marginal cost production because you do not have to burn any fuel. You put the solar panel in, and it works for 25 or 30 years. Wind turbines are a similar thing. There is some operating expense, some maintenance, but it is very minor. Hydrogen production from that electricity is also all capex based, which means that marginal cost is almost zero and it is all about capitalising that expense. When you drive more and more volume—we have seen that with solar and wind—of renewable production, the cost plummets because it is all based on capex, and capex—capital expense per kilowatt production—reduces quite rapidly when the volume grows. The same thing will happen with electrolysis.

The main difference between fossil fuels and the green hydrogen approach is that with fossil fuels you have the cost of extraction for every tonne of fuel and it generally is growing because it gets harder and harder to extract. With green hydrogen, the marginal cost of producing a kilogram of fuel is almost zero, and it is all about capital expense lowering, and it will happen with volume. That is why we are so optimistic.

Q104 **Jerome Mayhew:** Glenn, from the perspective of one of the big operators, do you agree with that assessment?

Glenn Llewellyn: Yes, fully. We see various regions, the International Energy Agency, all targeting low cost for green hydrogen production, in many cases around the $2 to $3 per kilogram mark. If we get to those numbers, we are talking about marginal, small cost increases compared

to kerosene, but it looks like there is huge potential there. It is one of the reasons we are pushing this pathway so hard now.

For sure there are lots of things that need to happen in order for us to get there. We need a push from several sectors, we need the ability of consumers like aviation to develop the technology. We are all, the transport sector and the maritime sector, pushing for that. Then we need the development on the supply side to be scaled because it is through economies of scale, the industrialisation almost, of the energy sector in those areas that we are going to get to these low costs and therefore reduce the cost of the transition, essentially.

Q105 **Barry Gardiner:** Glenn, can I pick up from you there when you were talking about the biomass-based fuel types? What specifically are you talking about, what land use requirements would that impose to produce the volume that is required in the scenarios and what constraints do you see coming from the constraints on land use?

Glenn Llewellyn: I do not have specific numbers to share with you now, but we could follow up through a written submission. Essentially, biomass-based fuels come from some kind of biomass. Either that biomass is grown for the intentional purpose of being solely used for the production of biofuels or we can create biomass-based fuels from waste biomass products—reused oil, waste food, municipal waste. It depends on which pathway exactly we are talking about, what the scalability and impact are in terms of land use. What is certain is that there are more physical limits around biomass-based fuels because of their dependence on waste, and because of their dependence on agricultural land, than the synthetic pathways that we have been discussing, like power-to-liquid synthetic fuel and hydrogen.

Q106 **Barry Gardiner:** I welcome the fact that you have offered to write to the Committee to try to set out quite what volumes would be required. Certainly, from the charts that we have seen, sustainable aviation fuel is required at every level, but when it gets to long haul it is the only thing left in the box of cards. If you could provide us that information, it would be very helpful. Then we can compare it with the challenges in other sectors and how each might affect the other.

Glenn Llewellyn: I will just add one thing. The synthetic fuel, the e-fuel that we were talking about earlier, power-to-liquid synthetic fuel, which uses hydrogen as a feedstock and carbon that is extracted from the air as a feedstock, is also relevant for long-range applications. We are not wholly depending on biomass-based fuels for that sector.

Barry Gardiner: We had understood that. Thanks for clarifying. I will pass to my colleague, Ian Levy.

Q107 **Ian Levy:** Thank you. I will turn first to Hannah and Matt. Could I look at airports and what the challenges are to airports and to the infrastructure to make sure that we meet the demands and make sure we have everything in place? In a nutshell, what do we need to do to make sure

that this works?

Hannah Tew: Connected Places Catapult's Zero Emission Flight Infrastructure project, which is funded by the Department for Transport, has just published a White Paper that has identified some key priority areas for R&D focus. First, the storage of hydrogen, the distribution and the handling of it, and how you refuel and defuel your vehicle. Secondly, thinking about the electric charging, again the distribution and storage, the handling and also the batteries for the electric-powered vehicles. Thirdly, research into the future demand scenarios of airside use of green hydrogen and electricity within UK airports. The full paper will be published later this month and that will have more details on those priority areas.

Moving beyond that White Paper, we strongly welcome the R&D focus on aerospace, so that is explicitly the design and manufacture of the vehicles. However, we feel equal R&D attention is needed on the transition to the aviation system, with these priority areas on ground operations and integration with the wider infrastructure also—the other transport network and energy networks that are relevant.

Connected Places Catapult is investing in supporting UK airports to harness this innovation in decarbonisation and aviation digitalisation and to convene new clusters of innovative businesses working towards the provision of assets that can de-risk and stimulate investment.

Q108 **Ian Levy:** Lovely, thank you. Matt, is there anything you want to add to that?

Matt Gorman: Very briefly. I am going to start back on sustainable fuels and then say a little about zero-emission flight. Glenn put very well that one of the advantages of sustainable fuels that exist now is that you do not require infrastructure change at airports or in our pipeline system and you do not require changing planes. You can drop these fuels in today. As soon as we can produce them, we can start cutting carbon. We do need the right policies upstream—the mandate for production, the price support, the capital investment—to scale the market.

For zero-emission flight there are a number of pieces of research. We have talked to the Connected Places team, we got funding from Innovate UK's Future Flight to look at this exact question, the Future Flight programme. We are concluding research with Rolls-Royce, Cranfield, GKN and others, which we will publish in the spring.

The three big questions are how you get the new fuel—hydrogen—to the airport, how you store it, and how you move it around on the airport and fill up planes. It is going to be a key area for us to better understand because this is a shift away from a very well established kerosene network that exists at the moment. The good news is, from the initial work that we are doing, certainly for the early days of the market when the aircraft are smaller and there are fewer of them, we think truck

deliveries of liquid hydrogen, certainly for an airport like Heathrow, would be sufficient, possibly until the mid-2030s.

The kind of scenario you might need after that is needing a new pipeline system to bring gaseous hydrogen to Heathrow. You then need to convert it to liquid at Heathrow, some kind of liquefaction process, which would need power, and you would need a new storage facility to store it, and then quite possibly a new distribution system around the airport as well.

We do not have answers to all that yet. That is partly why we are doing the Future Flight research and we are bidding for a second phase so we properly understand this, and many other bodies are looking at it because it would be a very significant transformation programme for us. By the way, you need hydrogen at both ends of the route as well for it to work, so it needs to be a European and global move.

Q109 **Ian Levy:** Therefore, we have to have a network to make this work. The big question is, who pays for it? Is it going to be an industry-led payment or is it Government as well?

Matt Gorman: That is not something that we have looked at in detail yet. At the moment, the fuel system at Heathrow is owned and run by a consortium of oil companies. We have some interaction with that, but it is effectively a separate entity. You would expect, as you transition to the hydrogen economy, that some of the policies that the Government have in place to support that— That Government are aiming to make that kind of investment attractive. As Heathrow, we clearly want to be ensuring that we are doing what we can to enable that shift in infrastructure, but we are some way off understanding the costs and how they will be paid for.

Q110 **Ian Levy:** Could I turn to Val and Glenn? How safe is hydrogen? There is a certain anxiety in the public about getting on a hydrogen plane, but if you think about it, if you get on a traditional plane you are carrying a big payload of aviation fuel. Could you outline some of the measures that are in place for how we store hydrogen, how we transport it and how safe it is?

Val Miftakhov: Yes, hydrogen has been in use industrially for multiple, multiple decades. It is one of the world's most common commodities today. About 100 million tonnes are produced every year, mostly used in petroleum processing and fertiliser production and industrial uses, some in transportation—a growing but small portion of that. That means that in the industrial uses the safety aspects have been quite detailed already. We know how to produce it; we know how to transport it and we know how to store it safely.

In the mobile applications, over the last 10 years or so we saw applications in ground vehicles, material-handling equipment, maybe 50,000 vehicles worldwide, compressed hydrogen mostly. The light-duty vehicles, cars, about 15,000 vehicles, operated by non-qualified personnel, which is important, regular people fuelling them at fuelling

stations and driving them every day. The safety systems around that are well established. In aviation, we are looking to take those learnings and apply them to aviation as well and build additional parts of the safety framework.

Some of the fundamental properties of hydrogen lend it even better from the safety perspective to be aviation fuel—for example, ignition temperatures are higher for hydrogen, about 500 degrees, versus jet fuel, which is about 200 degrees. Some of the accidents out there were post-hard-landing fires that were due to hot brakes igniting and the jet fuel leaks. That is not really possible with hydrogen.

Also, hydrogen when it escapes, if you have the structural integrity issues with the tanks, it escapes upwards and it dissipates very, very quickly. You are not going to have hydrogen pooled on the ground by your aircraft. It is very, very difficult to maintain flammable or explosive concentration of hydrogen in any kind of open space. Some of those things make hydrogen a potentially safer fuel than jet fuel. There are some third-party studies as well from NASA and a few other agencies.

Q111 **Ian Levy:** When hydrogen is compressed, is it safer at different stages?

Val Miftakhov: The compression storage technology has been quite advanced. Again, in all the ground vehicles that is what is being used. These are sturdy composite containers where the compressed gas is contained. The types of test that they go through include, for example, firing into those cylinders with high-calibre rifles and guns to test them against penetration and things like that.

Another interesting test is a bonfire test. All the tanks that go into the ground vehicles, in the passenger vehicles, are subjected for five minutes, I believe, several minutes, to an open fire to make sure that there is no detrimental effect there. It is quite well matured technology at this point.

Q112 **Ian Levy:** Thank you. Glenn, do you want to add anything to that? Do you want to come in?

Glenn Llewellyn: To add that we have been using kerosene for decades, and maybe the general public is not aware that we are using so much kerosene on the aircraft because we have implemented policies and procedures around the aircraft in terms of operation that ensure the very safe handling of kerosene. It needs to be well thought about and well designed. The aircraft itself, the design inside the fuel tanks, for example, in terms of gauging systems, in terms of tanks themselves, pumping valve distribution systems, have gone through a very rigorous safety procedure before we fly those systems and bring them into commercial service. As a result, we have achieved a pretty impressive safety record, one that I feel quite proud of.

There will be no compromise in terms of the safety requirement that we need to achieve if we introduce other energy sources, including

hydrogen. What will change is the technology that we use to meet those requirements. We will have sensing systems for hydrogen leakage, for example; we will have twin-walled tanks and potentially in some areas pipework. We will have ventilation systems, which need to be implemented in order to achieve or exceed the safety levels that we achieve today with kerosene. The key message there is that there will be no compromise.

Ian Levy: I think when we get to that point where we do start flying with hydrogen, the public anxiety is there, but when we get the message out as to how safe it is, that will make people feel a lot happier.

Q113 **John Mc Nally:** My questions are on Government support for zero-emission flights. Matt, we have heard that the Government have a decarbonisation transport strategy. In your opinion, how well are the Government supporting the development of zero-emission flight?

Matt Gorman: Reasonably well, but there is always more to be done. I will talk very briefly about SAF. I will say a little about zero-emission flight, but colleagues will be probably better placed.

Let me go back a step. The first thing I would say is that the Government's ambition on net zero flight is clear. Aviation, like every sector, needs to get to net zero by 2050. The establishment of the Jet Zero Council last year was very welcome to bring together Government and industry, chaired by the Secretaries of State for Transport and for Business, to agree and drive a joint plan. The ambition of that group is transatlantic flight within a generation without harm to the environment. That is a very clear ambition. On SAF as well, sustainable fuels, the Government have set a clear ambition of SAF in the UK by 2030.

Earlier, I talked about three key policies that are needed. The first is a mandate, the Government's requirement for the production of SAF. The Government consulted on that last year. They are planning a further, more detailed consultation next year and legislation by the end of 2022. That is good. We need to keep that moving and hold to that timetable.

The second thing that we need is a price-support mechanism, something that helps to close the price gap with kerosene, because SAF is up to five times more costly at the moment. Contracts for difference have been hugely effective in scaling up offshore wind in the UK and we think a similar model could be applied for SAF, but the Government need to move quickly now to consult on that and set out proposals.

What we are seeing in the SAF market is significant investment beginning to flow where the policy landscape is supportive, particularly in the States where they have introduced a tax incentive, the blenders credit for sustainable fuel, and in parts of Europe where there are plans for a mandate and some incentives in different countries as well.

The risk for the UK is that we should be well positioned to take a lead here. We have chemical engineering expertise, refinery and pipeline

infrastructure, and concentrated aviation demand, but the risk is that if we do not put the right policies in place quickly, we will fall behind and lose not just the decarbonisation but the economic opportunity on SAF. Remember, this is a real opportunity to invest in exactly some of the nations and regions of the UK that the Government have an ambition to level up—Scotland, Wales, the north-west, the north-east, Humberside—but it needs to move quickly with those policies. The final thing is mandate price support and some capital funding from the Government and/or loan guarantees. They have announced some funding, so that is good.

On zero-emission flight, we are less close as an airport. We have backed the overall industry call for a doubling of funding to the Aerospace Technology Institute over the next 10 years, which invests alongside manufacturers in research and development. In the spending review there was an increase in funding. It was not as significant as we had asked for. Colleagues Val or Glenn from Airbus are probably better placed to comment on exactly where that has got to, but we do think there needs to be ongoing investment R&D. Aerospace manufacture is one of the sectors the UK excels in. In aerospace we are still the second largest or among the largest in the world and we should invest so that we take advantage of this next generation of technology.

Q114 **John Mc Nally:** Thank you. It is quite well accepted that we are quite well ahead, but it is maybe the political will that needs to be kick-started here to make sure that that this continues and not just have everything in place. We seem to have a lot of things in place, but we certainly need the political motivation to make that happen. There is no excuse, I do not think, for these things not going ahead.

Hannah, could you give us a brief comment on the same question, and then Val and then I will move on to my next set of questions?

Hannah Tew: There is a lot to celebrate here, as previously mentioned. The opportunity in aviation also requires investment, aviation being the complex system of systems that enables the aircraft to fly, from booking your ticket to when you arrive at your destination, be that you or your goods. That complex system of systems requires a programme-of-programmes approach to unlock the full potential of that in the UK.

The Government have invested in Connected Places Catapult with the Zero Emission Flight Infrastructure project this year. That is setting out a roadmap for the infrastructure. Now is the time to scale that to a national R&D asset in a real-life setting that suppliers can come and unplug and play. The investment in aviation will lead to high-skilled jobs, and therefore there is an opportunity for these to be sited in areas that are in need of investment.

The opportunities around the integration of new classes of vehicle also should not be overlooked. For example, it was discussed in a previous session of evidence here that the implementation of small scale enables

the technology to be better understood, from which it can therefore be scaled.

The one thing that the UK also needs to talk about is the modernisation of the rest of our aviation industry. Aerospace modernisation is under way, but there is much to be done to keep our aviation and airport systems competitive. There is a big white space around aviation at the moment—in digitalisation, for example—and that is not being addressed enough.

Now is the time for the UK to step up a gear. Connected Places Catapult is investing in supporting the UK airports to harness innovation in decarbonisation and digitalisation, and continued support from the Government for implementation and de-risking is considered necessary.

Q115 **John Mc Nally:** Can I ask another question on similar lines, Val? We have heard from others that the ATI funding in particular is absolutely essential and vital to development. Can you tell us why the industry needs so much Government support to reach net zero?

Val Miftakhov: The UK has a huge opportunity here to lead the world in these technologies, in zero-emission technologies. We have seen already a great start to that. My company originally started in the United States and now most of our presence is in the UK because of the Government support. We are building our facilities here in the UK and hiring people here in the UK as well and building the technology and intellectual property in the country.

I think the UK is already doing a lot, and ATI and BEIS support was quite critical to us to achieve what we have achieved already, but I second Matt in saying that we need to see more. This is a huge problem. It is a huge industry, pre-pandemic $1.5 trillion worldwide, and it is one of the fastest-growing transportation industries. We are coming out of the pandemic and we will see further growth. That is the size of the prize. We need to have corresponding investment in bringing the technologies to the world.

Over a long period of time, zero-emission technologies will become the most important technologies to leverage worldwide. Initially, we will have the sustainable fuels, the synthetic fuels, that exist today and are able to start decarbonising aviation, but over a long period, 2050 and beyond, zero-emission will play a very critical role and we need to be investing in that early on.

Q116 **John Mc Nally:** I can see where that would lead to a lot of the green-skilled jobs—all the infrastructure that is needed from schools, universities into that—and you can make that connection quite clearly. If we are going to get there faster, we certainly have to put the investment and the money into that.

Glenn, is it fair to say there is a greater focus on developing sustainable aviation fuel rather than zero-emission flight since it is easier to use

these so-called drop-in fuels?

Glenn Llewellyn: We definitely need both, but we do absolutely need to make sure that we do not lose sight of the zero-emission propulsion system potential. Our view is that this is a cross-sectorial potential. Investment made in aerospace—in fuel cell technology, in liquid hydrogen technology, in gas turbines that are using hydrogen—is an investment that is not only going to benefit the aviation industry; it is going to benefit other industries as that subsequent generation of technology will find its way back to the ground sector in later stages. It is a common investment that we can be making here.

We have worked as Airbus in the UK in several partnerships with the UK Government through the ATI on several occasions, Wing of Tomorrow being a huge success. The Aerospace Integrated Research and Test Centre, the Aerospace Growth Partnership—we have delivered super results out of the various collaborations that we have been developing there. Now we need to be looking at the investment required to decarbonise. It is the biggest challenge that society has ever faced; it is the biggest that aviation has ever faced. We need a step change in the investment in the UK through ATI. We are talking about around £3.8 billion to 2030 and we believe that that will unlock industry investment of up to £27 billion by 2050.

What I would highlight is that companies like Airbus, global companies, are looking at two things when we look at investing in different locations. The first is technology because for our purposes we want the best possible technology solutions. We are looking for teams that have the highest potential, and technologies that have the highest potential.

The other that we have to look at is cost. If the UK Government are supporting the projects and the activities in the UK with public support, this, obviously, helps us in achieving our ambition. This transition is going to be costly in terms of investment for the various industries that are going through it, so cost is a parameter that we have to look at. We think that the UK is in a great position now. It has laid out an exceptional ambition, but we need to see the step change in terms of investment to map—the, let us say, practicalities of it with the ambition.

Q117 **John McNally:** You would probably be aware that ScottishPower's Whitelee windfarm is viewed as the largest electrolyser in the UK. It is producing green energy, but primarily it is for hydrogen and green local buses, which I am quite proud of as we have the best bus leaders in the world in Falkirk. I am sure Robert will agree with that. The question is, where are you planning to source your hydrogen from when your flights are commercially available? Will you be tapping into this facility that we will be producing there?

Val Miftakhov: Yes, definitely renewable energy, so the likes of the wind production that you mentioned, the solar production, and other renewable sources. We have done a good bit of that already. Our partnering with the EMEC Centre out of Kirkwall, for example, and also

partnering with Octopus Energy, which is one of the largest utilities here in the UK building on-site electrolysis production. Initially, Cranfield Airport was our first base, and now at Cotswold Airport in Kemble at larger and larger scale.

Shell, an oil and gas company, is one of the investors in ZeroAvia. It is quite interested in leveraging its presence in aviation markets and in fuels overall to bring green hydrogen production to the airports and to the vicinities of airports. There is a lot of interest from the utilities, from the oil and gas companies and other energy sectors, to power this transition. Again, as I was talking earlier, the fundamentals of producing this fuel are great over the long term and we will see seed kilometre cost on green hydrogen becoming lower than fossil fuel pretty quickly once the volumes come in.

Q118 **John McNally:** A final thought. Is it better to have these areas that are producing hydrogen closer to the site they are being used to fuel rather than further away? Is that a huge advantage?

Val Miftakhov: Of course, until we build long-distance pipelines for hydrogen, the transportation of this fuel is going to be relatively expensive. That is why we are looking to bring as much of this fuel production ideally to the airport location. Close to the airport is the next best. We think that it will be possible economically to put electrolysis production on site at the airports with local renewable electricity. It is easier to bring electricity than hydrogen to a lot of these places. We are definitely one of the first companies that are trying to do this, and starting to do it on the commercial scale very, very quickly.

Barry Gardiner: For the benefit of viewers who are watching the proceedings, we have referred to ATI and I think it is probably sensible that we explain our acronyms. We are talking about the Aerospace Technology Institute, which is a joint enterprise between Government and industry to the tune of about £3.9 billion. It is a substantial investment, both public and private sector. I pass to Helen.

Q119 **Helen Hayes:** Thank you very much, Chair. My first question is to Matt Gorman. Heathrow Airport announced in February 2020 that you had become carbon-neutral as an airport. Can you explain what that means, what is included in the definition of carbon neutrality, what you did to achieve what you have achieved, and what external independent validation there has been of that process?

Matt Gorman: The carbon neutrality refers to our own buildings and infrastructure at Heathrow; we are a big site. We had already shifted to 100% renewable electricity, so, effectively, this is about offsetting our consumption of, primarily, gas to heat the airport, and also of our own vehicle fleet at the airport. It is quite a tight definition, but it is in line with what other airports internationally have done when they have talked about carbon neutrality.

Externally, our global trade body, Airports Council International, has what it calls an airport carbon accreditation scheme, which we are part of, providing external verification of that. It has an external advisory board and, by the way, all our carbon data that we publish each year as part of our reporting is externally assured by auditors as well.

The broader point I would make is that we have seen a real shift, rightly, around carbon-neutral where you will invest in offsets. In our case, it was some UK nature-based solutions: tree planting and peatland restoration, but also international forestry projects. We see a real shift to a focus on carbon removal over the next 10, 20, 30 years out to 2050. We do think that robust, certified, natural climate solutions have a role, and there is a real opportunity where we have some residual emissions to continue investing, particularly in the UK in forestry and peatland restoration to stop peatlands emitting and to start them absorbing carbon.

Over time we will see that shifting—certainly from the mid-2030s—to engineered removals. We are seeing some early investments beginning to flow: Climeworks has a plant in Iceland, and Carbon Engineering investing in the US and looking in the UK. We are keen to explore what opportunities there are for us to start to invest in that technology, both to remove carbon and to help the market to scale.

Q120 **Helen Hayes:** Do you have further plans, either in relation to those residual emissions that are currently being offset, or in relation to using your procurement powers, your supply chains, your contracting arrangements with franchisees, for example, in the airport, to expand the definition of the carbon that is emitted as a consequence of the airport and to bring those emissions down further?

Matt Gorman: Yes. I have talked mostly today about what we would call carbon in the air, so everything to do with aircraft, and that is 95% of our footprint, but the 5% on the ground we have more influence and direct control in some cases. We have to get to net zero for both by 2050. For some bits of the footprint on the ground, we think we can get to absolute zero and do that sooner than 2050. Clearly, if we can do that, that is good.

To bring that to life briefly, for our buildings our big remaining source of emissions is gas heating, and we are just scoping out an investment programme—which will probably run to 10 to 15 years—to move away from gas to heat the airport to some form of electric heating solution, so that will be a significant step. If I look beyond the big source of emissions on the ground, it is from what in airport speak we call surface access—how people get to and from the airport on the ground; that is passengers, colleagues, freight and so on.

Clearly, there is a big shift under way nationally towards electric vehicles, and potentially hydrogen vehicles, as to our earlier conversation, for some bigger vehicles. What we need to do is ensure we are enabling and not blocking that shift, so we are either investing ourselves or allowing others to invest in the kind of changing infrastructure that will help that

shift at Heathrow. Again, we think we can get for the whole airport, leaving aside the aircraft that I talked to Barry Gardiner about earlier, close to absolute zero by 2050, which is what we need to be, or at absolute zero by 2050, which is what we need to aim for.

Between now and 2050, at the moment we are looking at whether we might invest in removals for some bits of our footprint to become net zero earlier than 2050. We have not published a firm plan, but it is something we are looking at.

Q121 **Helen Hayes:** What about the difficult question of modal shift in relation to the emissions produced by people getting to the airport? It is still for many people much easier to drive to Heathrow than it is to get there by other means of transport.

Matt Gorman: Agreed. Our approach to emissions from surface access is twofold. I have talked about enabling people to charge EVs, but you are absolutely right: alongside that we continue a very strong focus on public transport modal shift. For passengers, we have recently updated our target. By the end of our next five-year investment period—2026—we want 45% of passengers to be using public transport to come to the airport. Pre-pandemic, we were at around 40%, and that will come through particularly the opening of Crossrail and providing a connection from central London to Heathrow, but also ongoing support for both bus connections and long-distance coach connections to Heathrow, including slightly longer ahead, the connection to the HS2 network via Old Oak Common.

What we are also saying is where people are driving, we are encouraging them to car share, so we also have a target for our colleagues to reduce what we call single occupancy cars—someone driving to work on their own—to 57%. I need to check the level we are at now, but it is higher than that at the moment. To reduce that number, encouraging people to car share, and what we are saying with EVs, where people are driving, we want them to drive electric vehicles, so it is that combination of steps.

Q122 **Helen Hayes:** I accept the validation point about the carbon neutrality claim you are making—that that is within the definition as recognised around airport buildings—but what is the approach you are taking to communicating what you have done and what you have yet to do? There is this challenge, with all the work around reducing carbon emissions, that people are lulled into a false sense of security. If people understand the claim that Heathrow is a carbon-neutral airport, isn't there is a risk that somehow, the wider problems associated with international travel—associated with air travel, associated with driving to the airport, with consumption that happens at the airport, all those things—are minimised because there is a headline claim that perhaps does not relate to the entirety of the challenge?

Matt Gorman: Yes, it is a good question. We have always been really open in all our communications about the whole footprint that we have. I suspect we were one of the first airports, if not the first, globally to be

regularly reporting on all the flights leaving Heathrow as part of our carbon footprint, for example. We published a net zero plan a couple of years ago, which we are updating early next year, that covers all those emissions—flights, surface access, buildings. We have never sought to just focus on one bit and overclaim.

It is interesting because my experience of the very active debate on aviation and climate change in the UK over many years now has been there is a very clear understanding that the airport is one part of the picture, but its flights are important as well. I agree we do need to communicate clearly on that. We launched a campaign before the pandemic to talk about our approach on climate change. Yes, talk about what we are doing at the airport, but put that very clearly in context. We are planning to restart that over the next year, but welcome your feedback on whether you think we are doing that well enough, because we have to be open about the whole thing and have a clear plan across that whole footprint.

Q123 **Helen Hayes:** Thank you. My next question is to Hannah Tew, and it is really to expand that discussion and to ask, what work is going on across the country at other airports to reduce carbon emissions on the ground?

Hannah Tew: Thank you. The context from which we approach this is that an airport is a city in microcosm—it is a transport network; it is a smart city; it is a connected place—and there are lifestyle and system changes that are required to reach net zero. As an example, we are soon to publish an R&D action plan that we have worked with the stakeholders, and some of the airports, including Heathrow, contributed to that. Some of these innovative solutions are already beginning to come to the fore.

I would like you to imagine for a moment that you are going on holiday and you are using flights to get to where you are going and you are carrying, essentially, your own body weight in luggage and then on to that flight. It may be that you are going to a net zero airport; however, there will be an implication to you taking that luggage with you.

Imagine the carbon saving if your luggage could travel in a lower carbon way. That is a solution that two companies—Airportr and Sherpa, as examples—are developing today, but looking at using lower carbon surface transport to move your luggage around, so door-to-airport or home-to-hotel. You do not need to be lugging all your luggage to the airport yourself. Therefore, that unlocks different transport methods to get to the airport because you now no longer have to consider your luggage in your movement.

These are the types of activity we are working on within the Catapult network to de-risk airports investment for operators and innovators. We saw in the last few weeks, easyJet at Bristol airport doing the first net zero turnaround, so there is a lot of activity going on. AGS up in Glasgow also has a strong sustainability activity that it is reporting.

Q124 **Helen Hayes:** It is interesting to hear about those more innovative

solutions but what progress is being made on the more straightforward things, like switching energy supplies to zero-carbon energy in airports across the country? Is Heathrow an outlier in having switched its energy suppliers or is that happening as a matter of course in airports up and down the country? What is the level of progress?

Hannah Tew: I can answer in two parts. The first part is I do not have my hand on that information so I can get back to you. What I can say is, reflecting on what I have seen from the airports with which we work, our sustainability plans include energy from sustainable sources. Whether they are currently doing that or whether that is part of their plan, I am optimistic that that is certainly on the mind of some of the more active airports that we are talking to.

Q125 **Helen Hayes:** Thank you. My final question is to Matt and Hannah. Given the ambition in the industry, should the Government be bringing forward its target of 2040 for zero airport emissions? Can it be done sooner, and should the Government be pushing the target forward?

Matt Gorman: Speaking for Heathrow, as I said, we think we can achieve that for our own airport infrastructure: zero emissions by the mid-2030s. The investment needed, the solutions at different airports, will vary but my view at the moment would be 2040 is a good end point to aim for and it is 10 years ahead of the overall goal for the economy. That does not stop individual airports—ours and I am sure others—moving more quickly than that.

Hannah Tew: I think it would be worth investigating the different types of airport in answer to that. Heathrow is a bit of an outlier in the way it is regulated and the size of it as an entity. There will be different approaches for different sizes of airport. Also, where they are sited. We heard earlier about airports or ports that are sited near where energy is produced. They all have a much different outlook from airports that are, let us say, landlocked and do not have access to land to put up turbines, for example. I think there will be a spectrum of solutions and answers, and some of those will be further out than others.

Q126 **Helen Hayes:** Hannah, it would be really helpful if you wrote to the Committee on the question of the progress that is being made towards zero emissions airports on the ground, because it might be a recommendation that this Committee wants to make that bringing the target forward is an achievable thing and the Government should be doing that in order to drive progress with greater urgency. Given the size and complexity of Heathrow, and the progress that has been described here today, it might seem like not too big an ask that smaller airports elsewhere in the country are also making a similar level of progress. I think we would welcome that additional information, if it is possible to provide that, in order to inform the recommendation to put to Government.

Hannah Tew: We will see what information is available and get that to you.

Helen Hayes: Great, lovely. Thank you very much.

Barry Gardiner: Robert, you wanted to come in with an additional question.

Q127 **Mr Robert Goodwill:** A quick follow up to Matt regarding some of the choices that people make in how they get to your airport. If I wanted to go to your wonderful terminal five from here, I could get on the tube. I could go up to Paddington on the tube, or in a taxi and use the Heathrow Express, or I could walk to Victoria coach station and get a coach to Scarborough right through to the terminal. Has the airport looked at how it might be able to advise passengers about the carbon footprint of those choices because I really would not know? I can work out what the cheapest way to get the airport is, which is probably the underground, but in terms of the carbon footprint it would be very difficult for me to know the greenest way to do that. Would you look at some toolkit or giving passengers advice as to how they could make those choices?

Matt Gorman: It is a good question. I do not think we have in carbon terms. To the question earlier on public transport from Helen, I think we clearly promote public transport—be that bus or coach or tube—as an option and all of those will be lower carbon than driving. I do not think we have looked at a carbon toolkit, but it is a good thought. It is something I will take back and have a look at.

Mr Robert Goodwill: It will be like having the calories on the menu, I suppose.

Matt Gorman: Yes, indeed.

Q128 **Barry Gardiner:** Robert, thank you very much. Yes, Hannah, did you want to come in?

Hannah Tew: If I may. I think this is a really interesting question and there is some science behind it that probably does need some investment in order for us to be able to make educated decisions. I think the debate around the transport from London to Glasgow ahead of COP26 was really interesting, where a train and flight both took around five and a half hours. I think there was about 20 minutes in it—it wasn't much—but the cost in the carbon was estimated and there is quite a lot of debate around the science that was used with regards to how that carbon was calculated.

I think we would welcome some investment in understanding the lifecycle analysis of the different transport modes. I think that would be very helpful.

Q129 **Mr Robert Goodwill:** Do not forget the carbon in the infrastructure because once a plane is in the air, there is a lot of concrete and steel in railway lines and motorways and all the rest.

Hannah Tew: Absolutely.

Barry Gardiner: And runways. That concludes the first panel, and I want to thank you all, Val, Hannah, Matt and Glenn, for your evidence this afternoon. It has been really helpful to the Committee. We can move now to our second panel. Thank you.

Examination of witnesses

Witnesses: Leo Murray and Tim Johnson.

Q130 **Barry Gardiner:** Welcome to our second panel of the afternoon and perhaps, gentlemen, you could introduce yourselves, beginning with Tim Johnson?

Tim Johnson: Thank you and good afternoon. Thank you for the invitation. My name is Tim Johnson. I am the director of the Aviation Environment Federation. We are an environmental NGO active in the UK on behalf of community groups around the UK's airports and airfields. We also represent the environment NGOs at the International Civil Aviation Organisation, the UN body that oversees international aviation.

Leo Murray: I am Leo Murray. I am Director of Innovation at Possible, the climate charity. Possible works at the interface where people meet the low-carbon transition and we need people to do things differently. My role there involves coming up with solutions to difficult climate problems and in that capacity, one of the things that I came up with was a frequent flyer levy, so they originated that idea.

Q131 **Barry Gardiner:** Leo, may I start with you? You have looked at the Jet Zero aviation strategy and, if I am right, you were not particularly complimentary about it. In fact, I think you called it "fatally flawed". Perhaps you could explain to us why and maybe talk about the importance of reducing demand as part of the tools in the Government's tool box.

Leo Murray: Yes, absolutely. Thanks, Barry. I think the simple answer to the question of why demand management is important in this picture is that every other analysis that has been conducted into deep decarbonisation pathways that has looked at aviation and hasn't been done by the industry itself concludes that demand management is going to be required. I should be clear that there is some nuance within that phrase of "demand management". It does not necessarily mean demand reduction. It can just mean attenuation of growth, so it can mean aviation continues to grow but at a slower pace than industry is predicting.

Q132 **Barry Gardiner:** That was the basis of the Oxford study, wasn't it?

Leo Murray: Yes.

Q133 **Barry Gardiner:** Do you want to elaborate on that?

Leo Murray: Last year, we did a paper that simply looked at lots and lots of net zero pathways where a lot of different organisations had come up. Every robust scenario that is consistent with the Paris agreement, and consistent with the UK's own climate change commitments under the Climate Change Act, contained an element of demand management. Since then, this has been corroborated by the International Energy Agency, which has produced its own net zero pathways. The OECD has produced more net zero pathways since we did that.

Everybody reaches the same conclusion—it is a different conclusion from that reached by industry actors who write these pathways themselves—that it is not possible to meet our climate change targets if we continue to seek to cater to all projected demand growth. If growth in air travel continues to grow unconstrained, we will fail to meet our targets.

Notably, among the people who say this is required are the Government's own statutory advisers, the Climate Change Committee. I have been following this for long enough to know the Committee has been saying this since 2009. No Government has ever responded to this recommendation from the Climate Change Committee because, politically, it is a bit of a third-rail issue. People do not really want to go near it. However, the Climate Change Committee has been saying this for 12 years. I think it is instructive to note that it is still saying that 12 years later and nothing has happened in the aviation sector in the intervening 12 years to make the Climate Change Committee change its mind about this.

What the Climate Change Committee says is that we cannot cater to more than a 25% increase in demand. The industry is projecting closer to a 70% increase in demand, so that is the difference. What is important here is the Climate Change Committee has this right in the way it has framed it. The Committee has described it as a backstop and, if we think of it as a safety net, what is happening here is we are being asked to take a leap of faith with the aviation industry that lots of their predictions around low carbon technology are going to come true. We are being asked to jump out of a window and, "Do not worry because we are going to catch you."

Unfortunately, if you look at the track record of the aviation industry with respect to these types of target, in the 15 years I have been working on this I literally cannot find a single example of a sustainable aviation fuel target being met that the industry has set itself. I have just written a research brief for an exhaustive piece of work that is going to look at every target that an airline or an industry body has set. If we complete that work in time, I will submit it as evidence to the inquiry. So far, I cannot find a single example.

What we are being asked to do here is step out the window and, "We are going to catch you." They literally have not managed to catch us on any previous occasion. If we do not want to go splat, what is needed here is a

safety net. That is how the Climate Change Committee is describing and thinking about the requirement for a demand management policy framework. We need it in case these unicorns do not arrive.

Q134 **Barry Gardiner:** It is always helpful to the Committee to try to frame things in terms of our eventual report. Would you consider it helpful if this Committee recommend in our report that the Government specifically respond with their view on the challenge posed by the Climate Change Committee in respect of demand management?

Leo Murray: That would be a tremendously helpful recommendation for the Committee to make. I might hazard you probably should not hold your breath because I count eight separate occasions—there may be more—on which the Climate Change Committee has asked the Government to respond to it.

Q135 **Barry Gardiner:** Let me move to Tim at this point and ask whether you were equally surprised that the Government did not directly include demand management in their Jet Zero strategy.

Tim Johnson: The simple answer to that question is, yes, we were surprised. I very much agree with Leo's characterisation both of the track record and perhaps what the Government have presented us with, building on the last session. It is all very exciting. There is a lot of stuff there that we can get enthusiastic about. That has reflected the Jet Zero consultation, but it is an exercise in what is possible rather than what is probable.

When you try to unpack that and look at the reasons why the industry goals that have been set in the past have not been delivered, there are three main barriers. The first has been weak regulation. For example, the standards that drive manufacturers on environmental performance tend to follow technology rather than lead it. Until recently—we do very much welcome the Government's decision to include international aviation and shipping emissions in the Climate Change Act, but to this point we have had very weak regulations—it has been very much dependent on industry setting voluntary targets and voluntary commitments.

The second one is that we have had a very low carbon price. We have had some inclusion of aviation in the EU's emissions trading system and more recently in the UK's emissions trading system. CORSIA has yet to impose any carbon price on aviation. Most of aviation does not pay a carbon price at all.

The third one is the price differential that we explored in the previous session between the current new tech and new fuels, which everyone accepts, at least initially, are going to be more expensive and the fact that its biggest competitor is relatively cheap untaxed kerosene. Unless you actually seek to address those three things, yes, you might get technology, but—to use an aviation reference, its landing point—the market it is landing in is not conducive to encouraging those technologies to come through and get into the aviation fleet. That is the sort of thing

that we expected to see in a Jet Zero strategy—not just the focus on technology, but all these enabling powers, the levers, the policies that were going to correct the market.

Just briefly, because I suspect we will come on to them during the course of this session, if there are three reasons why it has been broken in the past there are perhaps five things that we need to focus on moving forward. The first is to take an economy-wide perspective. We are looking at aviation in isolation. Yes, it needs hydrogen. It needs more renewables, but so does everyone else. How does that spread across the economy?

The second one is to take a climate wide perspective, so we are talking about zero carbon point, but we need to focus on aviation non CO_2 impacts, and they vary according to technology and fuels.

The third one is that, if you bring any new technology into the marketplace you need the airworthiness. The questions from Ian earlier around safety, you need airworthiness, you need certification, they are processes that are yet to be put in place. Even if we have the tech, we need to have these and be able to assess them.

The fourth one is the planning lead time around all the infrastructure that this would require. I think of the Velocys plant that is opening around the Humber estuary. That is a six or seven year process to go through planning and construction, and even looking now to 2030 when the Government hope to have modest ambition around sustainable aviation fuels, we need to see those plants and that infrastructure going through planning now if it is going to arrive in time.

The fifth one, and the most fundamental, is the uncertainty. If you talk to airlines and airports and ask them what their preference is and what they believe in, in terms of the future of technology, they will say, "We want everything, because we do not quite yet know which way is going to mature and come to market quicker." We want action on all of them. The Government's own Jet Zero consultation talks about the uncertainties. They talk about the scenarios they put forward as being illustrative. There is a lot we do not know, so, bringing all that together, again, these are things that are not in the strategy that we would need to see to have confidence in the ability for new tech and for SAF to make a big dent in aviation emissions, but bringing it all together. Because of our uncertainty point, we need to take a much more balanced approach to the policies and, yes, encourage genuine zero emissions for technologies to come forward, but, at the same time—Leo used the words "safety net"—you need to be looking at demand as well.

Maybe if I could just close on one point. It is not missing entirely from the Jet Zero consultation. Direct demand management is something that the Government have not sought to take forward at this moment in time. They do say they want the strengthening in carbon pricing. They do acknowledge that stronger carbon prices will have an impact on demand.

They do want to have a conversation with the public. They want to give people more choice and information when they book flights about their impacts. There are signs that we are moving into that territory on the indirect demand management side, but, I think, our bottom line would be that it is flawed. We said that it was incoherent and inadequate in our evidence to this Committee, and we stand by that. I think there is a lot more content that is required for us to have confidence and, therefore, demand management is a vital part of a strategy to move forward.

Q136 **Barry Gardiner:** You spoke about untaxed kerosene. Is there an argument that increasing aviation taxes or adding levies provides no support for decarbonising the industry or would your view be that it provides additional incentive to find an alternative way of doing things?

Tim Johnson: The question you asked the previous panellists was, what more does the Government need to do to help them? They all answered with various degrees of incentive and funding. If you do that, you are potentially locked into it long term. Some of the money the Government have made available at the moment is seed money and infrastructure money, and there is a case for getting some of this infrastructure started. You are locking yourself into that subsidy model because it looks to us that there will always be the cheap availability of kerosene and it will always come down to costs from an airline's operating point of view. Therefore, you have to use taxation, I think, to tackle what is currently this untaxed product.

The argument you get is that we cannot do that because it is largely something that is beyond the Government's control. That is not correct. People cite the Chicago Convention—ICAO's founding document—as a reason why you cannot tax fuel. Chicago does not say you cannot tax fuel. It says you cannot tax fuel that is already on board an aircraft when it arrives in a country. Quite rightly, it has been purchased and bought somewhere else.

Q137 **Barry Gardiner:** One would expect it would have its tax paid somewhere else.

Tim Johnson: Indeed, but what has happened is the air service agreements that exist between states, they have actually written that in much looser language and said, "No taxation." Things are beginning to change. When we left Europe at the end of the year. We were required to set an air service agreement with the rest of Europe to govern operations between the UK and our European partners. There is no such clause in that agreement that would prohibit the UK Government from at least taxing flights between here and Europe.

This is a tool that is at our disposal, and I am sure we will come back to other physical tools that could be used.

Barry Gardiner: The Glasgow Climate Pact, which the Government have just signed at COP26, specifically makes mention of taking away subsidies, so that would be another incentive for the Government to do

that.

Q138 **Mr Robert Goodwill:** When I was Aviation Minister, we discussed this and, of course, the problem will be that if you were hopping to Amsterdam you would just fill up in Amsterdam and not fill up in the UK where the tax was. Particularly on short haul destinations—a bit like Luxembourg and diesel, lorries—you just fill up at the cheapest place.

Tim Johnson: Yes, tankering is a real risk, and tankering is also a risk with things like a SAF mandate for exactly that reason. Fortunately, in this situation, the European Union recently published its fit for 55 proposals on how it intends to tackle emissions. It has kerosene taxation on its agenda; suggested rates that will escalate to something like 33 euro cents per litre. In this sense, the UK would be joining a broader alliance—a regional block, as it were—that would be taxing aviation. Therefore, I think in the end, the main threat would be avoided.

Leo Murray: I would say, in terms of things that the Government ought to be doing, one of them is diplomacy around air service agreements and taxing kerosene because, you are quite right, this is a problem, but it is no good to just simply wave at it and say, "This is very difficult because we signed all these agreements." Well, we signed those agreements, and we can revisit those agreements and, as Tim just described, there is activity on this front already, but, unfortunately, not as far as I am aware, by the UK Government.

Q139 **Barry Gardiner:** Again, gentlemen, if I can invite you to formulate what would be an appropriate recommendation for this Committee to make on that, could you put that into words for us?

Tim Johnson: I would be extremely pleased if this Committee invited the Government not only to look at the opportunity for kerosene taxation where current air service provisions permit. That would primarily be on routes between the UK and the EU. To pick up on Leo's point, start active negotiations with the countries where there are major corridors with the UK—we are primarily talking about the US and Canada, but also the Middle East—to see whether there is any meeting of minds. The Government at Glasgow launched their coalition of states that were committed to net zero aviation. That would be a good place to start, and it has the US in it. That would be a very interesting challenge that would help address one of the reasons that I think is inhibiting real progress within the aviation industry at the moment.

Leo Murray: The fundamental reason so little has happened is the availability of incredibly cheap kerosene. It is the only form of hydrocarbon fill that is untaxed by international treaty and it creates distortions in the market. It makes air travel artificially cheap relative to other forms of travel.

Q140 **Caroline Lucas:** Maybe I just zoned out for a second, but did you talk about taxing fuel within the UK, which we can do—

Leo Murray: We can do that tomorrow.

Q141 **Caroline Lucas:** We can do that tomorrow, exactly, so why do we not just start there? Can we add that to our Committee recommendations, please? There is also the example, isn't there, of it is going to cost you three times more to take the train to Glasgow than it would to fly and people sometimes do that.

Leo Murray: The United States applies tax to kerosene on domestic flights; it is a very low rate, but we could do this now.

Q142 **Caroline Lucas:** My first question is to Leo. You have kind of touched on this already, but perhaps you could say more about how credible you think the Government's pathway to decarbonising aviation is.

Leo Murray: To some extent we are all lay people here. I am not an aerospace engineer. I am a very close observer of this sector and I have been watching what has happened over the last 15 years. I have seen lots of these roadmaps and pathways to lower emissions come and go with the targets unmet. I think we can just use some heuristics here to test whether we think this is a credible pathway. For instance, they are assuming annual efficiency gains, which are much higher than the historical trend without really explaining why or how that is going to happen. You can pick lots of examples like that from the way that they have approached this. Every time that we diverge from the norm it is optimistically, so all the assumptions are towards optimism.

Now, I am an optimistic person by bent, and the charity I work for has optimism backed into our theory of change, but at some point it just becomes wishful thinking. The DFT has not explained why some of the assumptions in its modelling differ so much from the Climate Change Committee's and it has declined to explain when asked. That does not inspire confidence.

Q143 **Caroline Lucas:** Just on that for a second, earlier you were talking about the Climate Change Committee and saying that it was suggesting that aviation could grow no more than 25—

Leo Murray: Yes.

Caroline Lucas: At that point, did you tell us what your own view was about how much growth there is without basically ensuring that the rest of industry closes down to leave the space for aviation to—

Leo Murray: No, there are a very wide range of views on this. A lot depends on what inputs you put into your models, but where I differ from the Climate Change Committee's analysis is in—do you need to go and vote?

Barry Gardiner: We will need to go and vote.

Leo Murray: Where we differ is that the Climate Change Committee is assuming a very large market in carbon removals in 2050. This is something that does not exist at the moment. I say it does not exist. We just heard from Matt Gorman that Climeworks is going to need carbon removals and we are probably going to need them at a fairly large scale.

It is important to understand that Climeworks at the moment is $1,200 per tonne to remove a tonne of carbon from the atmosphere as an engineered removal. That is where the market is now.

CORSIA is $4 a tonne, so I do not regard the market in carbon removals as plausible. The scale that is envisaged for this when we are literally nowhere on this today. It literally does not exist. There is no commercial market in removals. There are some start-ups that are doing it. It is fantastically expensive. That is the basis on which the Climate Change Committee is projecting that we can continue to grow air travel, that these negative emissions technologies will become available to remove those, which do not exist in a meaningful scale today. I think that is very much veering into the territory of wishful thinking. I think it is the weakest part of the Climate Change Committee's whole net zero analysis.

Barry Gardiner: We are veering dangerously into the territory of missing our vote. At that we will adjourn for, I think, one vote at the moment. We should be back in 12 to 15 minutes.

Sitting suspended for a Division in the House.

On resuming—

Q144 **Barry Gardiner:** Right, we are quorate again so ready to restart.

Caroline Lucas: Yes, picking up where we left off, I was going to move to Tim Johnson and ask, your evidence was highly critical of the Jet Zero strategy's reliance on sustainable aviation fuel—I know we have touched on that too—so could you say a little more about that? If you did want to stray into issues of R&D that would be very interesting as well.

Tim Johnson: There are two things that are worth saying in addition to the comments before. One relates to the credibility of the modelling. Everything that is in the Jet Zero consultation assumes that SAF will make a 100% reduction in emissions and we do not believe that is the case.

Leo Murray: Nobody does.

Tim Johnson: In fact, there is this mismatch between the optimism that is in the Jet Zero consultation and the policy reality that faces Government when you try to pull the policy levers. If you look at the sustainable fuels mandate consultation that came out shortly afterwards, in that the Government define an eligible sustainable aviation fuel as having a minimum 60% reduction in emissions. Obviously, we welcome having a minimum threshold, but it is not 100. I think typically, most of the biofuels that are being advocated by industry at the moment make cuts around 70% or 80%.

There is certainly a modelling issue. There is also a modelling issue, in that the Government assume that all these things—including the technology in the SAF—come at zero cost. In other words, it has not done

a specific cost modelling exercise about what it takes to bring this to market. As a proxy in the modelling, there is the use of a carbon value. They use BEIS's carbon value from 2018, which in today's terms is about £70 per tonne of CO_2. However, that value was set before the UK moved to a net zero trajectory. It is based on the old Climate Change Act target.

If you look at the most recent Government carbon values, that carbon value has risen from £70 to approximately £220 or in that region. You do not even have an effective substitute. We are critical of the modelling.

We are also critical about the degree on which we think SAF will be able to deliver and be scaled. It is the reliance on SAF. Most of the short-term, near-term projects that industry has put forward and that fuel suppliers have put forward are based on waste. The thing with waste is we should be trying to reduce it anyway. You cannot build a scalable solution for aviation on having more waste; by definition, it is limited.

The point that has to be made around SAF—if it is not already obvious—is that when you burn SAF, whether it is kerosene or biofuels, it does not reduce the emissions that come out the back of the plane. They emit just as much out of the back of the plane as kerosene does. The fact is that the carbon has supposedly been absorbed at some point in the process. That clearly makes more sense for synthetic fuels because you are going to capture—if the technology exists, and when the technology exists, and it is affordable—the carbon you want from the air. You are going to process it into a synthetic fuel and then you are going to burn it again. It is a relatively closed loop.

When you start talking about waste materials, when that carbon was absorbed there is a time delay. I think these are all the things that suggest that the use of biomass for aviation is anything but— Well, it is a short term solution. We do not see it continuing, apart from the fact that, if you actually look at the way it is set up, the industry is asking for subsidy and support to build biomass plants. We do not see those being turned off after five years or 10 years; once they are there and you have had the investment in them, they are likely to continue to use the waste that we have. I wonder if that is actually going to inhibit the wider investment we need in things like synthetic fuels in the longer term; inhibit the investment that we need around hydrogen production facilities.

The industry has been very open in saying it is not pinning its hopes on one particular pathway. It wants all these things to come forward. You do very much get the sense that the current hot topic is the use of waste-based SAF and that is where they want the immediate investment to be centred. Once that is in place, we feel that it could lock us in.

Lots of different reasons whether it is the sustainability, whether it is the scalability, and the affordability I think we have touched on. Good reasons why we just do not think they will be there in the sort of volumes that the Jet Zero consultation hopes to deliver.

Leo Murray: If I could pick up from where Tim left off there.

Q145 **Barry Gardiner:** Briefly, if you would, Leo, because I am conscious that we only have three-quarters of an hour.

Leo Murray: Of course. Of the sustainable aviation fuels, which are genuinely sustainable, we are talking about power-to-liquids and we heard about that from the previous panel. Power-to-liquids is synthetic fuel that is made from, in principle, renewable electricity, so generating hydrogen from renewables. Tim made this point before, but I think it is really important to understand that there is an opportunity cost here. The Climate Change Committee is not an enthusiast for power-to-liquid fuels. I think the truth is it is really the only viable technological solution that we have available for decarbonising long-haul flights and that is pretty much an accepted fact. CCC is not keen on them because of the opportunity costs, because, in terms of the efficacy, carbon abatement units of renewable electricity can be used in many different ways across different parts of the economy. In the CCC's carbon budget assessment it says that using green electricity to power an EV is seven times more effective at carbon abatement than using it to make power-to-liquid fuels. That is fundamentally because it is a very energy inefficient process.

I already made the point about targets being missed, but I will give you one example. IATA—the International Air Transport Association—is a global trade body for the aviation sector. In 2009, it set a target of sourcing 10% of fuel from alternative sources by 2017. In 2018, the global industry was sourcing 0.002% of airline fuel use from alternative fuels—that is 7 million litres, or about 10 minutes of global jet fuel consumption. That is the scale at which these targets have been missed. It is not like they have got close to it and did not quite get there. It is that we were orders of magnitude out. IATA currently has targets for 2050 that would require a new refinery to be built every week and a half over the next 30 years. It is not plausible.

Q146 **Caroline Lucas:** Very quickly, my last two questions. Will reviewing the Jet Zero strategy in five years' time be too late? Should it be reviewed before five years?

Tim Johnson: The actual Jet Zero strategy—the final one we are yet to see—I think we will see that early next year and we hope it looks different from the consultation. Let us assume it does not. Yes, the idea of having a regular review, setting a pathway and having a regular review is a good one. Are your policy levers working? Do you need to do more or less? No, I think, given the importance of making sure that we make a real dent in emissions by the 2030s and if you look at all the trajectories that are in the Jet Zero consultation, emissions are still either about the level they are today or in one of them even higher than they are today by the 2030s. I would suggest the sooner we review it the better, because I think those near-term solutions are going to be fundamental to getting those long-term emission reductions that we need.

Q147 **Caroline Lucas:** My last question. Who should pay towards the costs of

decarbonising the aviation industry, where should that fall?

Leo Murray: I will start. Every sector of the economy wants a Government subsidy to be decarbonised. It is difficult and nobody wants to have to wear those costs themselves. It is true that, as it stands, the aviation industry has only been able to scale to the size that it is profitable by enjoying very, very generous tax exemptions. That is what has got us to where we are today. When you look at the function of aviation, what does it do, air travel and the economy? It is predominately—this is just statistics—a leisure activity undertaken by people at the top of the income spectrum, and 80% of flights are leisure flights. Most of the people who take them are frequent flyers and most of those frequent flyers are the top of the income spectrum.

Q148 **Barry Gardiner:** I think the figures are 61% for holidays and then 20% or so for—

Leo Murray: Visiting friends and relatives, yes, absolutely. That is an important distinction, but nevertheless the point is it is not business.

It is very difficult to say that this ought to be a priority for public spending on decarbonisation. It is a sector that has got away with having a free ride when it comes to its environmental effects for a very long time. It made sense in the 1940s, probably, to agree not to tax kerosene. Does it make sense today? Did it make sense 10 years ago? The answer is, no, it didn't. With the sector now coming and saying, "We would like to do this, but unfortunately we are going to need the Government and the public to pick up the bill." Most flights are taken by a very small proportion of the UK population. That is it. I think the industry should be paying for it. I am afraid the sector is not doing this spontaneously, so it needs to be made to do so.

Tim Johnson: Just a brief addition to that. I would also agree that it is the industry that should be paying. There was a call in the last panel for more subsidy and more investment by Government. There is not a shortage of potential interest from the private sector in doing this, but what they want to know is that they have certainty that that investment will be utilised by the airlines. If they provide the capital and the finance, airlines will buy. Fixing those things, I said at the beginning—the regulation and the market—would create the certainty that I think will bring the private sector more to the fore.

Caroline Lucas: Thank you both very much.

Q149 **Barry Gardiner:** Just briefly, Caroline did give you an invitation to talk about research and development, which neither of you took up. If you want to briefly touch on that. Briefly.

Leo Murray: Very briefly. The speaker from Airbus was asking for a great increase in public spending into aviation R&D, but the company that he represents is spending a much smaller proportion of its own revenue on R&D to that end than it was 10 years ago. This is pre-pandemic, in fact, I should say, rather than today. In 2008, they were spending about

9% of their commercial revenue on R&D; by 2018 that was just 4.5%, slightly less than that. I think it is important to situate these asks in context.

Q150 **John McNally:** I think you are absolutely right, by the way; you need the certainty of policy. Automatically, certainty of investment will follow on from that. That needs to be made absolutely clear, and it probably needs to be made clear over a period of 25 years that this is not going to change with any political party. That is probably the crucial part of the whole thing. However, I will move on with some questions on frequent flyer. The first is to explain the premise of the frequent flyer levy, why you think it is the most equitable option to reduce demand for air travel. I know we have touched on this, but could you expand on it a bit more, please? That would be very helpful.

Leo Murray: Absolutely. There is a difficulty here. We know we are going to need to manage demand. At the very least, we are going to need to manage demand growth downwards, below its unconstrained level. The simplest way to do that, or the most obvious mechanism we have, is through fiscal measures. The simplest way to do it is simply increase taxes in a blanket way on all air travel. This has been opposed by IATA for many years on the grounds that the impacts will fall disproportionately on people at the bottom of the income spectrum, on low-income people. This is the argument made by the industry against the increasing aviation taxes. It has some merit. Demand for air travel is not very price elastic. It is extremely income elastic. Your propensity to fly goes up disproportionately the more you climb the income spectrum, whereas changes in the ticket price have to be very large to deliver a relatively small response in demand.

What that means is that if you are intending to manage demand within safe limits, which is the purpose of the frequent flyer levy, you need to turn the knob up so high, you need to turn the dial so high on the tax you are applying that people at the bottom of the income spectrum are priced out of air travel altogether. This is what the environmental movement has been accused of by the aviation industry for many years. "You just want to price the poor out of the skies." The frequent flyer levy is a response to that, inasmuch as that argument has legitimacy. Most air travel is undertaken by very small numbers of people. The reason this is effective as a demand-management measure is that almost all the environmental damage from air travel is done by a very small share of the population: 15% of people in the UK take about 70% of all flights. When it comes to domestic flights—we looked at this the other day because of all the furore—2% of the English population take 90% of all domestic flights.

Q151 **John McNally:** Did you say 2%?

Leo Murray: Yes, 2%. Unfortunately, the way the data was captured means it only applies to England now. I cannot compare the figures with Scotland, but this is what the data shows: 90% of all domestic flights are taken by just 2% of the English population. We did a piece of work earlier this year that looked internationally. We asked, "Does this pattern hold?"

It holds everywhere you look. Air travel is not undertaken at all by about half the population. Half the UK population do not fly in a given year, and about another 20% fly once. Then you have another 5% to 6% who take two flights. Those are the normal patterns of air travel. That is what most people want from air travel. They might want to see relatives. They might want to take occasional holidays, and that level of air travel can be sustained, in that we can meet those levels of demand with power-to-liquid fuels, for instance.

It is plausible—it is feasible—that we could scale up production of zero-carbon fuels to meet that level of demand. What we cannot do is cater to these people who are pushing the average up. There are people in the domestic-flights data who report flying every day. They are clearly commuting to work by plane. That is equivalent to 350 family holidays—not quite, but you take my point. Targeting demand-management policy, if you are going to accept that there is a need for it—that has not happened in the Government yet; they are still repudiating an expert consensus around this—then becomes a question of whose flights you are going to stop happening. There is a tactical question here around the politics of doing this in practice. Can we really get the public to wear this? There is also an in-principle question about whether it is fair and equitable to make it impossible for any air travel for people who are at the bottom of the income spectrum. People may have family overseas, and so on.

The point of a frequent flyer levy is to maintain access to some air travel for everyone, even in the context of shrinking overall demand to within a safe level for the climate. That is the premise of it. Frequent flyers do most of the damage ,we should target policy at them and consequently it is very popular with the public. It is much more popular than proposals to just blanket increase taxes on air travel. When you ask the British public about a range of policies that they might support, it is very high up the list, and there were very high levels of support for it. Both the UK citizens' assembly on net zero and the one that the Scottish Government did recommended a frequent flyer levy. We see now public poll after public poll supporting it. That is because fairness is absolutely consistent as the No. 1 concern of the British population across the political spectrum. Left to right, everybody wants this to be fair, and they look at the situation of air travel, where most of the damage is done by a small number of people, and they say, "We should not stop people taking an annual family holidays, or seeing their mum. It is these people who are doing most of the damage, and that is where we should target the policy."

Q152 **John McNally:** We can understand that. It seems fair, even working in a place like this. You have just mentioned that people travel from Glasgow or Edinburgh to here every week, twice a week, or maybe more than that. It also takes into consideration the anecdotal evidence, which would tell you that there are people from Paris and Brussels who are flying here for financial institutions. I do not know if they are doing it every day, but they are certainly doing it very frequently. That takes me on to the next

question. For this frequent flyer to work, would it have to be implemented globally, or should we just start somewhere?

Leo Murray: It would work better if it were done regionally or globally. That is true of everything we heard from the previous panel as well. Because of the nature of the aviation sector, it is intrinsically international, so that makes it hard for anybody to move first. However, UK residents take one in 12 international flights. We take far more international flights than the people of any other country. That does not mean we fly more. People in the USA fly more than we do on a per-capita basis, but they fly domestically. The UK is responsible for an enormous share of all international flights. We are also very good at capturing data. We have a very tight ship when it comes to people coming in and out of the country, relatively speaking. We are well placed to implement a frequent flyer levy before others.

It is certainly more complex to administer than an air passenger duty. The Treasury like APD; it is a very, very simple tax, airlines collect it for the Treasury, and it has to do very little validation. It goes back and it checks records occasionally to make sure that people who said they were exempt really were who they said they were. The Treasury does not really have to do much, and money just comes in. The Treasury published a note with their APD consultation earlier this year explaining why they were not going to implement a frequent flyer levy. Because it had been in the discourse so much, it felt it needed to explain why it was not going to do it. The problems are not really around the nuts and bolts of the administration. The problem is recognising a need in the first place, because it is more complicated, and you would only do it if you recognised that you needed to manage demand within safe limits in a fair way. That has not happened. The problem is there is not a recognised need for it, and it is more complicated. It is also not rocket science. The idea that it is more complicated than, for instance, switching all the infrastructure in airports so you can put hydrogen in planes is obviously fanciful.

Q153 **John McNally:** Being mindful of the time, have you done an economic impact assessment or calculated impact on businesses and trade in the UK? Tim, should we be focusing on demand-management measures and on the number of trips or how far people fly? I will go to Tim first, and then come back.

Tim Johnson: I do not say this in any way to undermine FFL. The point I think we would both agree on and want to convey to you is that there is a broad range of instruments, depending on whether you are focusing on reducing emissions, on taxing passengers, or the equity point. First of all, you have to start this discussion with a willingness to increase taxation for aviation to help tackle this problem. If you accept that then there are different ways of doing it, Leo has outlined FFL. There is an idea that Dr Richard Carmichael put forward to the Committee on Climate Change on behaviour about how to influence behavioural change. He said an alternative approach, maybe, was to tax the air miles, rather than the

number of trips. It is just a different way. There is much more of a focus there on the emissions, rather than on the passenger incidents in terms of the number of trips they make. There are those two.

In our evidence we also talk about things you could do. We covered kerosene taxation. The optics around companies, airlines, credit card companies, offering MR rewards seems to send the wrong signal to the travelling public, that this is something to be encouraged. You could tax that. They tax that in the USA; there is a tax on the use of MR rewards. There is a broad range of things there that you could use, once you have taken that first step to say that taxation is something we need to do.

Q154 **John McNally:** Any final comments from you, Leo?

Leo Murray: With respect to economic modelling, you need to recognise that you need a separate, parallel regime for businesses. Businesses cannot be responsible for an individual's flights, and individuals cannot be responsible for flights they have been sent on by businesses. You have to have corporate entities that are also subject to a separate, parallel regime. There are some sectors, some SMEs, that are very, very heavily dependent on regular, international flights, and would be disproportionately impacted. You would need to have some mitigation measures for them, and potentially exemptions. In terms of modelling impact, we have looked at the socio-economic impacts for passengers with the New Economics Foundation, and if you implemented the frequent flyer levy, it sees nearly all the reduction in flights come from people in the top fifth of the income spectrum, and a small increase in flights by people in the bottom fifth, because the proposal is to allow the first flight with no tax at all.

It is not quite published, but I have just finished proofing a piece of work with the Autonomy think tank that is looking at the impact on jobs. This is obviously a very live issue; the pandemic has eviscerated the aviation sector. What we have found is that for every job that would be lost in the aviation sector from a strategy of reducing flights, it would create up to three jobs in other sectors. Air travel is not very jobs rich. It is very capital intensive. Domestic tourism, on the other hand, is really quite labour intensive. I need to get this on the record in this session. The UK, prior to the pandemic, had a £34 billion tourism deficit. That is the difference in the balance of payments between money spent by UK residents overseas and money spent in this country by foreign visitors to the UK. This is never talked about. It is never discussed. Whenever I bring it up with Ministers or with people from the industry, they look at their shoes and shuffle around. That is a bigger number, £34 billion, than the total direct value of both the aerospace and air travel sectors to the UK economy.

If you look at airports like Doncaster Airport, regional airports function in the economy principally to funnel money out of the region by taking the wealthiest residents of that region and to another country so they can

spend their money somewhere else. Constraining air travel is mostly a good thing for the UK economy.

Q155 **Helen Hayes:** Continuing on the theme of taxation, the Government say that they have re-aligned passenger duty to environmental objectives. Is this the case, and what impact will the changes that were announced in the budget have?

Leo Murray: It is very unfortunate. Tim and I sat in on a round table with the Treasury Minister as part of their consultation on this. The actual carbon impacts of cutting domestic APD are very, very low. They are very, very low. The message that it sent in the run-up to hosting a vitally important international climate conference was exactly the wrong message, and there is abundant academic evidence that this stuff matters. It undermines public confidence, and it undermined our climate diplomacy.

Q156 **Barry Gardiner:** Leo, again, for the sake of anybody watching these proceedings, could you please explain that the reason the impact is very low is because there is a cap in the sector? I think it is important that you expand on that.

Leo Murray: Yes. I will let Tim speak about the ETS. I think what it sought to do was create an extra band, super long haul, and the emissions associated with super-long-haul flights are much higher. Domestic flights are only about 4% of total emissions from the UK.

Tim Johnson: To put some numbers on it, the total emissions from domestic flights prior to the pandemic were about 1.4 million tonnes to 1.5 million tonnes a year. Total aviation emissions in the UK were 38.5 million tonnes. That is where the 4% comes from. If it stimulates more domestic flying, we are talking about a marginal increase. To your question, we do not think it was balanced. It said it had done the new ultra-long-haul band, and there would be an increased revenue take from that, but I think Treasury's analysis, which was published alongside the statement, showed that the two measures together result in something like a £30 million per year loss in terms of APD.

Q157 **Helen Hayes:** You have talked a lot about the frequent flyer levy as an approach to reducing the environmental impacts of aviation. Are there any other measures that we have not talked about yet this afternoon that could have impact in reducing the environmental impacts of aviation? Again, on that question of how you rebalance the taxation system, is there anything else that has not been discussed this afternoon that would be a useful policy intervention?

Tim Johnson: I gave some other examples where I think you should look at taxation, starting with kerosene taxation. There is still an absence of VAT on air travel tickets. That is something that could be explored. What we make a fundamental distinction on is that when air passenger duty came in it did not come in, contrary to what the industry says on occasions, as an environmental tax. It came in because there was no tax

on aviation fuel, or VAT, and therefore, APD is a contribution to Government spending. You then have this question that we have asked before about how you increase carbon pricing. That has to be taken in addition. We are not advocating a single measure here. You could use all these as a package—kerosene tax and an APD, or an MRs levy or an FFL. They can all be used in totality. I think we have raised the biggest issues that the Committee needs to consider.

Leo Murray: We have certainly spoken about kerosene tax at some length. We have spoken about carbon prices. I want to clarify that the frequent flyer levy is not proposed as an alternative to kerosene tax. We still require a kerosene tax because it is not good if you only tax passengers. It creates distortions. There are some flights that are only freight. You do not have any incentive to maximise the capacity on planes if you are only charging passengers.

In terms of other measures, I would like to get on record our idea to set a date by which fossil fuel private jets would no longer be able to use UK airports. We have heard a great deal from the industry as part of this inquiry about the market readiness of things like electric flights. Electric flights are only useful in a very small set of circumstances. They are excellent for highlands and islands, trips to Jersey, and domestic flights. They are not much use for other things, because fundamentally, they are good for small aircraft.

Private jets are small aircraft. I did a piece of work about two years ago looking at every route that is flown by private jets across the European economic area, and 80% of flights by private jets could, in principle, be completed by electric planes, which are in development for market entry in the next decade. If you look at the effect of the Government announcing a ban on the sale of new ICE vehicles in the automobile market, it is transforming it. It is the certainty. It is the policy certainty that you need. With respect to private jets, the user base there has access to a great deal of capital. They are not short of money. If you want to accelerate the entry of electric flight to the market, the best way you can do that is tell the billionaires and celebrities and CEOs who use private jets today that in eight years' time they are not going to be able to land at these airports using a fossil fuel private jet. I guarantee you that they will come back much quicker with an electric plane.

Q158 **Barry Gardiner:** Just to be clear, you are suggesting that if this Committee were minded to recommend that, the appropriate date would be 2030? Is that correct?

Leo Murray: It aligns with other things, and it aligns with industry projections for market entry, so yes.

Tim Johnson: I will make one very brief addition to that. We have talked about fiscal measures to tackle demand. We have also talked about the optics around MR rewards, or the optics around slashing APD for domestic flights. The other optics that were called out by the behavioural change team that advises BEIS was the Government's approach to airport

capacity. At a time when we are trying to signal the urgent need to decarbonise a sector, we are giving a green light to airport expansions. The very specific recommendation from the Committee on Climate Change was not only to limit demand by 25%, but to say the capacity to support that 25% already exists and, therefore, if you are going to add more you need to think about where you can cut it. You can redistribute it, but there should be no net increase. Despite the pandemic, there is no shortage of airports coming forward wishing to expand. We have Luton, Gatwick and Heathrow. We have Stansted that has recently had permission to expand, as has Southampton. Bristol has just been through a public inquiry. Leeds Bradford is awaiting a decision from the Secretary of State. Manston Airport is to reopen as a freight hub. There are many more with ambitions to grow. Simply saying, "No more net airport capacity," would be a very simple way of dealing with the demand question.

Q159 **Caroline Lucas:** What are your views on the emission trading schemes and offsetting emissions? I remember Tim talking about this about 15 years ago when I was the Rapporteur in the European Parliament. How have things changed since then, and can ETS schemes be made to work?

Tim Johnson: Yes, I remember it well. They have taken time to develop and transition, and the UK model follows very closely the EU model. Now we have an intent. It may be on ICE—if I read the media headlines correctly this week—because of the spike in oil and gas prices, or certainly in gas prices. Certainly, the intent is to phase out free allowances over time; to ratchet down the cap so that it gets tougher and tougher. That will increase not only the volume of emissions that the industry has to pay for, but because of the demand and supply relationship it will increase the price. We recently saw the UK ETS price cap £60, which compared to the price of an offset looks like a much more effective way of trying to manage aviation emissions.

When it comes to offsets, I think it is a very different story. There are credibility issues, and I think you have seen a lot of airlines in recent months moving away from the idea of offsets as an idea that has had its day. You spend far too much time trying to demonstrate the additionality. They are not always trusted. Aside from the issues around credibility, there are the issues about what ICAO's CORSIA scheme will do.

Q160 **Barry Gardiner:** Could we set out the acronyms? The International Civil Aviation Organisation.

Tim Johnson: Indeed. The UN's specialised agency, the International Civil Aviation Organisation's scheme to offset emissions, originally above a 2020 baseline. The sector as a whole would be responsible for offsetting the growth beyond that 2020 baseline. Because of the pandemic, 2020 suddenly looked like a very low baseline. ICAO agreed to an industry request to change the baseline to 2019 levels. Any industry analyst will probably tell you that we are unlikely to see 2019 levels of growth for at least another two to three years. Therefore, it is very unlikely that

CORSIA is going to apply any offsetting obligation and, therefore, a carbon price on international aviation any time soon.

The scheme is set to finish in 2035. Its cap obviously is not aligned with a Paris-compatible pathway. It is for those reasons that the Committee on Climate Change has said to the Government that the offsets delivered, when they are delivered under CORSIA, should not be eligible for the UK's carbon budgets under the Climate Change Act. Therefore, it has its place. In some parts of the world, it gets the measuring and the monitoring, and it starts to exert a very small carbon price. I am not saying that is completely worthless. It has its place. As a tool to deliver UK carbon emission reductions, I think it has very little to offer in its current format.

Q161 **Caroline Lucas:** Going back to the ETS for a second, is there still a concern, which I dimly remember, about if you are trading a tonne of emissions at sky level versus one on the ground? As it was originally designed, it is not taking into account the extra contrails, the nitrogen oxides and so forth. How much of an issue is that?

Tim Johnson: The science has improved since you were Rapporteur.

Q162 **Caroline Lucas:** It was quite a long time ago.

Tim Johnson: These things seem to move incredibly slowly, yes. We are lucky that in the UK we have some of the foremost atmospheric scientists in our academic institutions, whether that is at Reading, Leeds or Manchester Metropolitan, working on non-CO_2 emissions. The latest science suggests that the total climate impact to date from aviation is three times that of CO_2 alone. In other words, non-CO_2 impacts are two-thirds of the problem.

When we talk about all the measures today, and focusing on carbon, you have to keep in mind what this does to non-CO_2, and start to put a price on non-CO_2 impacts, and look again at whether the time is right to factor them into these schemes. That is a very opportune moment, I think, to pause and revisit that, because we seem to have lost momentum on that issue around the scientific uncertainty that exists. Policy makers put it to one side and said, "We will come back to it when the science matures." Europe was in a good place then, and we have not followed it through, and it is still just as much of an issue today as it was then.

Q163 **Caroline Lucas:** The recommendation could be that the Government—who would we ask to do it?

Leo Murray: It is now just the UK, because we have our own ETS. There are enormous difficulties. The ETS design is very complicated anyway. There are enormous difficulties in quantifying and monetising the value of the additional warming impact. What we do know is—just for clarity—every time the carbon is traded under either of these schemes, and when a tonne of carbon from a ground-based source is being traded from a tonne of carbon that has been emitted in the upper atmosphere, there is

a very large net increase in warming that is not reflected in the design of the scheme.

Q164 **Caroline Lucas:** It is not part of the debate anymore, which is why I was asking.

Leo Murray: Yes. It did not go away; it was just ignored.

Q165 **Barry Gardiner:** The non-CO_2 climate impacts mean that aviation counts for 3.5% of global warming, rather than the 2.5% of global CO_2 emissions. I think they are significant. There are some cooling effects and some warming effects, but on balance the warming is stronger.

Leo Murray: Yes. It depends on what time period you look at it over, and the way the scheme is designed it values carbon impacts over 100 years' time. It is very difficult to monetise. My view is that is one of the reasons why these types of scheme are the wrong approach.

Tim Johnson: However, for the technology people on the previous panel, what would hydrogen aircraft do? Are hydrogen contrails different? Are they more or less of an impact? There is some evidence to suggest that SAF could, if you reduced particulate matter, make an improvement, but some could go the other direction. We have to keep that wider picture in mind.

Q166 **Caroline Lucas:** I am very aware of the lack of time. How effective has ICAO been at driving net zero aviation?

Tim Johnson: At the moment, ICAO's climate goal is to stabilise emissions at or below 2020 levels. It does not have a 2050—

Leo Murray: It is not consistent at all.

Barry Gardiner: I think we have that point. Let us move on.

Q167 **Caroline Lucas:** I think we have the next one as well, because the next question is, how is the UK showing leadership on net zero aviation internationally? But I will leave you with that thought.

Tim Johnson: I will say one very quick thing. We touched earlier on the coalition that the UK launched during COP with 20 other states that is trying to get ICAO at its assembly next year to adopt net zero as a long-term goal. That is worthwhile, and those processes mean that you have to start negotiations early. We commend the fact that the Government are trying to start those negotiations early. ICAO is not a regulator. ICAO's decisions, even if it adopts net zero, tend to be aspirational goals. They are not binding. Everything that it does is given legal effect by countries putting it in law. What has really shown climate leadership is the fact that we have put international aviation and shipping emissions into our carbon budgets. That is what other countries should do as well, to hold the industry to account and to make sure we deliver on these commitments.

Q168 **Barry Gardiner:** Those two points are very helpful to the Committee,

because it is always good to be able to preface any criticisms of the Government in our reports with congratulations on what they are doing. It softens the pill.

Tim Johnson: It is unprecedented. No one else has done it and it really is very significant.

Q169 **Barry Gardiner:** In the final couple of minutes—this is going back to the previous questioning Caroline gave you and the responses you were giving in relation to possible recommendations from this Committee—should Government revise the carbon price in line with the net zero target, so that instead of being £70 it becomes £220 per tonne? Was that one of the recommendations you would suggest?

Tim Johnson: The recommendation would be that before the net zero strategy is published, we see up-to-date aviation forecasts. The latest set was produced in 2017. That is the basis on which the net zero consultation calculates emissions. We should certainly adopt the new BEIS value for carbon, which is the £220. Ideally, you would also do a cost analysis of SAF and technology to make sure that that carbon value was sufficient to capture that, or whether there were additional costs that needed to be factored in.

Barry Gardiner: The lifecycle modelling of biomass SAF and the opportunity costs should be modelled. Thank you very much. We have just managed to close before our 5 o'clock deadline. Tim Johnson and Leo Murray, I thank you both very much for your evidence to us this afternoon. It has been a really good session.